Umamimi robotic horse ears – using configurable code profiles to replicate individuality in equine animatronics

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ABSTRACT

In this descriptive paper, the author reports developing a set of prototype, programmable animatronic, robotic horse ears. Applications are: (i) when worn by a human, to explore interaction between horses and humans, using (technologically enhanced) body language and (ii) when used stand-alone, as a potential robotic companion for solo, stressed or recuperating horses. This work compliments literature on horses' use of ear-based attentional cues and their understanding of human facial expressions. The ears have: user-triggered movements (when worn by a human) and random movements when there is no user input. Also proposed: a path to modelling the personalities and moods of real, individual horses, using an ethogram for logging horse ear movement characteristics. Configurable code profiles are built from these observations, customising the random movements of the ears. This work suggests possibilities for studying a horse's response to experiencing her own ear movement characteristics reflected back at her, via technology.

Author Keywords

aci; adafruit; animal-computer interaction; animal-robot interaction; animatronics; arduino; horse; horse-computer interaction; human-animal interaction; robotic ears; robotics; umamimi

ACM Classification Keyword

CCS → Human-centered computing > Human computer interaction (HCI); CCS → Computer systems organization > Embedded and cyber-physical systems > Robotics; CCS → Human-centered computing → Interaction design → Interaction design process and methods → Interface design prototyping; CCS → Human-centered computing → Interaction design → Interaction design process and methods → User centered design;

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INTRODUCTION

The Umamimi robotic horse ears are a prototype device, not intended for significant quantitative evaluation, but more allowing the author to explore what it means to be a horse-human assemblage, using expressive ears to communicate both intention and emotion. Umamimi is also inspired by the machines developed for animatronics and puppetry.

The Umamimi device is both capable of user-triggered movements (with ear positions corresponding to a horse's fundamental moods and behaviours) and random movements (when the software events necessary for user-triggered movements are not being generated).

The user-triggered movements are actioned when the human makes small changes to the inclination of her head. Umamimi's built-in accelerometer then sends these accelerometer readings to the software, which responds with the following pre-programmed ear movements: fully forward, fully back, either ear turned outward. When the robotic ears are in neutral (meaning that the accelerometer and therefore the device is level), a range of random default ear flicks and movements have been specified, which may be customized via configurable code profiles.

A later section of this paper will describe the user-triggered ear movements and how they correlate to the literature on 'EquiFACS: The Equine Facial Action Coding System' [15].

Umamimi's random ear movements are fully customizable via software programming (the configurable code profiles). Subtleties of ear movement expression may be modelled, to reflect the varying personalities found in individual horses. Ultimately, it is possible to imagine different profiles could be developed, with variations in the speed, range, frequency (of events) and degree of synchronization displayed in the ear movements.

In this initial phase of Umamimi's development, the author does not fully evaluate a route from: (i) observations of a real horse's ear behaviours to (ii) a Umamimi configurable code profile, representing the ear movement characteristics of the observed real horse. However, it does theoretically propose how this mapping might take place, with a workflow that includes: an ethogram of ear movements for observing real horses > logging software > an Excel spreadsheet for processing the raw logging data and then applying the calculations necessary to create a configurable code profile.

The paper provides sections describing Umamimi's hardware and software development, explaining how the configurable code profile was implemented, to replicate individual horse personalities.

What are the origins of the 'Umanmimi' name?

Umamimi (馬耳) means 'horse ears' or 'horse eared' and the author has used this name to reflect the Japanese tradition called 'Kemonomimi' (獣耳 'animal eared') [3], which is found in both anime and manga.

HORSE EARS AND THEIR USE IN EQUINE COMMUNICATION

There is literature in the field of equitation science suggesting that horses follow the directional ear movements of other horses as attention cues and that they also respond to human gaze cues in the same manner [14][16][17].

The equine ear is a complex anatomical component. As a veterinary / horse owner's textbook states:

> *"Each ear can be swiveled independently through 180 degrees, or laid back, shutting it off. Such mobility is achieved with 16 auricular muscles attached to the base of the pinna. Humans have only three such muscles, all of which are vestigial. Easily visible at the top of the head, a horse's ears are used to signal emotional state and intent...In response to directional sounds, a horse flicks an ear towards the source, or, if the sound is coming from the front, pricks both ears forward"* [9].

UMAMIMI'S USER-TRIGGERED EAR MOVEMENTS

The default position for the Umamimi ears is 'neutral'. Beyond this, in response to changes in the user's head orientation, Umamimi has four predefined movements (see also Table 1):

- Fully forward
- Fully back
- One ear turned (left)
- One ear turned (right)

EquiFACS and the fundamental ear positions

EquiFACS (The Equine Facial Action Coding System) [15] is a methodology documenting all the possible facial movements of a horse. It is a detailed taxonomy of the discrete facial expressions and their underlying muscle contractions.

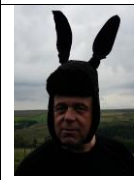
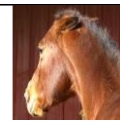
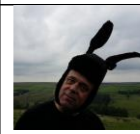
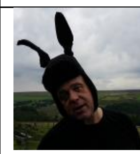
Equi FACS	Horse move	Umamimi user-triggered ear movements
Neutral		
Fully forward		
Fully back		
One ear turned (left)		
One ear turned (right)		

Table 1. User-triggered movements

The following EquiFACS entries correspond to Umamimi's five positions (neutral, plus the four predefined movements):

- Neutral - The general neutral ear position of a horse, as seen after a release of a previous movement with the ears returned to neutral
- Fully forward - positive attention / intense interest / curiosity / EquiFACS 'Ear Action Descriptor 101: Ears Forward'
- Fully back - agonistic / anger / aggression / irritation / grumpy / warning - EquiFACS 'Ear Action Descriptor 103: Ear Flattener'
- One ear turned - towards something of interest / divided attention - EquiFACS 'Ear Action Descriptor 104: Ear Rotator'

Table 1 compares the EquiFACS ear positions (column 1), an example of a horse performing a corresponding ear position (column 2) and Umamimi performing the ear position (column 3).

THE UMAMIMI HARDWARE

The Umamimi hardware is built on a metal framework, with black faux fur covering, two micro servo motors each move an ear independently, in incremental steps, through a maximum range of 180 degrees. At the heart of the device is the Adafruit Circuit Playground Classic all-in-one electronics project board [1]. This board is powered by a programmable ATmega32u4 processor.

THE UMAMIMI SOFTWARE

The software for Umamimi [12] was developed in the Arduino IDE [2] using the Arduino programming language. This is a set of C/C++ functions, where, in the initial pre-compilation phase, function prototypes are automatically generated. This is then passed directly to a C/C++ compiler (avr-g++) and the executable is uploaded (via a USB interface) to the Adafruit Circuit Playground Classic.

Implementation of the configurable code profile to replicate individual horse personalities

The code profiles are used at times when the Umamimi device is not receiving input from the user. This might be considered the device's default behaviour, when idling and awaiting instructions. Configurable code profiles might be developed and stored for many different horses, or horse emotional states. The choice of horse is made (from the 'library of possible horses') when the code is compiled and uploaded to Umamimi. Each profile is a C++ header file (for example 'default_horse.h') and it contains three defined values, as shown in Table 2. Later in this paper, there will be an explanation of how these three defined values might be derived from the observation of a live horse.

Defined value	Range	Definition
PERCENTAGE_TIME_ EARS_STATIC	1-100%	The % of time that the ears are not moving
DELAY_BETWEEN_EACH_ STEP_WHEN_EAR_MOVING	Any value in micro seconds	Ear travel time (break each movement into steps and specify pause length between steps)
PERCENTAGE_EAR_ RANDOM_MICRO_ MOVES_TENDING_ TOWARDS_ UPPER_LIMIT_ OF_RANGE	1-100%	% of ear movements that tend towards upper limits of a preset range

Table 2. The elements of a Umamimi configurable code profile: the three defined C++ values in a header file

A ONE-OFF 'PROOF OF CONCEPT' FOR THE WORKFLOW: FROM THE ETHOGRAM TO THE CONFIGURABLE CODE PROFILE

The initial work described in this paper focuses on building the hardware and software prototype. It is also suggested that the individual personality and behaviour of a horse might be replicated. This section briefly describes a possible approach to mapping the data collected using the 'Ethogram for horse ear movement characteristics, indicative of arousal / vigilance level, mood and personality' (see Table 3, in the next subsection).

Proposing a horse ear movement ethogram for approximating individual horse moods and personalities

Umamimi's random movements (when the software events necessary for user-triggered movements are not being generated) are determined by software-based, configurable code profiles (as previously discussed). In order to develop a workflow from a real horse to Umamimi, a suitable methodology is required for observing and capturing the ear movements of real horses.

The principle observational tool in ethology is the 'ethogram': "a set of comprehensive descriptions of the characteristic behaviour patterns of a species" [6]. In this subsection, a very simple ethogram [13] is proposed for observing the ear movement characteristics of horses (see Table 3).

Using the ethogram and the CowLog software to observe 'test horse #1'

This is a one-off run through the workflow, using a video clip of a subject referred to as: 'test horse #1'. Cowlog [4][5] is a free software tool for logging activities and behaviours from video. It is primarily used for ethology and animal behaviour studies. Cowlog allows the specification of individual behaviours (including those detailed in an ethogram). These can then be used to log behaviours in real time, as they occur during video playback. The configuration for a Cowlog session comes from an XML json (JavaScript Object Notation) project file, containing the behaviours to be logged (this is effectively the ethogram). Each behaviour appears as a clickable button on the interface. At the completion of a logging session, the results are saved in a CSV (Comma Separated Value) file.

Ethogram for horse ear movement characteristics, indicative of arousal / vigilance level, mood and personality

Behaviour
1. Movement in one or both ears - short travel and fast / flicky
2. Movement in one or both ears - short travel and slow
3. Movement in one or both ears - long travel and fast / flicky
4. Movement in one or both ears - long travel and slow

Table 3. Ethogram for horse ear movement characteristics, indicative of arousal / vigilance level, mood and personality

If this approach were to be used for logging ear movements (as is being suggested as a method for mapping from a real horse to Umamimi's configurable code profiles), the focus is on behavior frequencies, rather than durations. Therefore, Cowlog was only clicked to record when an ethogram behavior occurred, rather than marking the start and end of a behavior.

The observer clicked for each discrete instance describing or demonstrating the associated ethogram behaviour, even if they occurred consecutively.

Throughout the logging session, the observer referred to Table 3. An 'Ethogram for horse ear movement characteristics, indicative of arousal / vigilance level, mood and personality'.

The steps performed for an observation and logging session in Cowlog were as follows:

1. In Cowlog, the appropriate XML / JSON project file (contained the codified ethogram behaviours) was selected.

2. A video file (in the MP4 format) was selected. Note: changes to the screen layout were often required, so that the video playback window was appropriately positioned and sized, relative to the Cowlog interface.

3. Playback was started by clicking the Play button.

4. As the video playback progressed, the appropriate behaviour button (for example: '(1) Short fast') was clicked, as a particular behaviour was observed. Note: at any stage, if the observer needed more time to consider which was an appropriate behaviour to log, then CowLog's playback could be paused, for as long as required. Playback and logging was then continued, by releasing the pause button. In fact, as behaviour durations were not being studied, it was also possible for the observer to use rewind and fast forward to move through the video. This ensured that the video was thoroughly analysed.

5. When the video playback completed, the output CSV (Comma Separated Value) file was then ready for review.

Using the data from the ethogram (via CowLog) in a Microsoft Excel spreadsheet to calculate the defined values in Umamimi's code configuration profile

The output CSV file from CowLog contains each instance of an observed behaviour and it's start time. It does not include total frequency counts for each ethogram behaviour. Therefore, it is necessary to have a Microsoft Excel spreadsheet which calculates total frequency counts for each behaviour. This sheet also carries out other calculations to derive the required code configuration profile values, as needed for Umamini.

Table 4 summarises the key values from the spreadsheet. The last three rows (capitalized) are the defined values for the code configuration profile (the horse-specific C++ header file, compiled with the Umamimi microprocessor software). After compilation and uploading the revised software to the device, the behaviour of the robotic ears was informally viewed. No further evaluation was planned, or conducted, at this time.

Parameter	**Value**
Total time video observed	73 secs
Ethogram #1 short & fast - freq	18
Ethogram #2 short & slow - freq	1
Ethogram #3 long & fast - freq	0
Ethogram #4 long & slow - freq	4
Est time ears moving	18 secs
Est time ears static	55 secs
Total freq long travel behavs (3 & 4)	4
Total freq fast behavs (1 & 3)	18
Total freq short behavs (1 & 2)	19
Total freq slow behavs (2 & 4)	5
Total freq ALL behavs	23
PERCENTAGE_TIME_EARS_STATIC	75%
DELAY_BETWEEN_EACH_STEP_ WHEN_EAR_MOVING	7
PERCENTAGE_EAR_RANDOM_MICRO_ MOVES_TENDING_TOWARDS_UPPER_ LIMIT_OF_RANGE	17%

Table 4. Summary values from Microsoft Excel spreadsheet used to calculate the defined values for the code configuration profile

CONCLUSIONS

This paper has documented the development of: the Umamimi robotic horse ears prototype, an ethogram for approximating individual horse moods and personalities, configurable code profiles (as C++ header files) to represent individual horses and a workflow (from the ear movement ethogram to a configurable code profile for Umamimi).

Further work on Umamimi: qualitative and ethnographic / autoethnographic

The author is planning to conduct further research with Umamimi, directly involving real horses. The plan is to introduce a human, wearing robotic / animatronic horse ears into a small group of horses, with the intention of reflecting on the nature of interspecies communication and the extent to which it is dependent on species-specific anatomy.

The objectives would be:

● To video the interactions between the human wearing the robotic ears and the horses.

● To capture interesting horse-human interaction vignettes on video for later discussion and qualitative analysis.

● For the human to reflect (in writing) on the experience of interacting through body language and temporarily being part of the horse herd.

● To describe the process of the 'making' of the technology (hardware and software) and its introduction to the horses.

The potential for a broader Umamimi ethological / quantitative study featuring multiple horses – observations and logging using the ethogram

If the ethology-based, observational methodology was further explored (for mapping from real horses to the Umamimi prototype), then issues or both intra- and inter-observer reliability would need to be considered.

For this initial trial of the ethogram and related methodology, only one trial observation and logging session was conducted ('test horse #1' - as previously discussed). It has been suggested that a reliable ethological observer should possess two traits: (a) general skills (training ethological methods) and (b) skills and experience relating to the specific species under study [6]. With a suitably experienced observer, repeating and verifying logging sessions is not usually considered necessary (although it will always increase rigor). Where there are concerns about either the use of one observer, or 'inter-observer reliability', then various approaches may be employed: (a) the use of a recognized 'expert observer' (external to the study) to conduct a repeat session (b) a 'calibrating observer' or (c) a consensus across the observations of several qualified observers.

If the ethogram is used in future studies, it might be useful to consider repeating the observation session, using one of above approaches (expert, calibrating observer or consensus) to increase reliability and to minimize observer bias.

Before the workflow proposed in this paper (from real horse ears to the robotic ears) could be used in a more rigorous setting, quantitative observations of the device (when modelling specific moods and personalities) would need to be conducted. Potentially, the ethogram in this paper might be used for comparisons between real horse ear behaviours vs. Umamimi.

Umamimi's potential as a robotic companion for solo, stressed or recuperating horses

There is existing research describing the use of physical mirrors in equine housing [8]. Reflections provide the illusion that a companion is with a lonely or stressed individual equine. For a social species that experiences stress when deprived of conspecific company, this is a fundamental welfare issue.

Robotic horse companions (or possibly just the identified essential anatomical elements required for communication – for example a head with animatronic ears) might provide an alternative to a mirror. Particularly, in situations where keeping a second horse stabled for a long period of time is neither practical, nor ethically appropriate for the companion. Umamimi hints at approaches where the body language characteristics of an individual horse (either the stabled horse herself, or possibly a more confident, relaxed field mate?) are captured. These might then be reflected at the lonely horse, via a partial or full-bodied horse robot. This could be customizable with different profiles / personalities to see which produced the most relaxed behaviours in the horse. This has the potential advantage that the stabled horse can be comforted by the presence of a more confident companion, rather than their own stressed reflection. This might prove to be a greater comfort.

ETHICS, WELFARE AND ANIMAL-CENTRED DESIGN

At this stage in the Umamimi project, live interactions with horses have been informal and minimal. The data of live horses has been video-based.

The author has referred to the 'Ethics - guidelines for framing nonhuman animal-based research in an ACI context' [11] and has endeavored to closely follow these recommendations.

The Umamimi project is inherently framed from an animal-centred perspective and supports the statement: "our commitment to non-human animals: build only what they want or need". [10][18]. In this case, the 'what they need' is satisfied by the researcher's intention to enhance human understanding of equine body language.

With reference to Mancini's five ethical principles for animal-centred research [7], the researcher has respected the horses as individuals with agency. In addition, the author fully supports there being an axiomatic duty of care for any live horses (at this stage, indirectly) involved in this project. Consent from the nonhuman participants and their human guardians has (thus far) not been required. However, the author has already devised a protocol for the stress-free introduction of the device to any interacting horses and participants will always be free to retreat from any study.

Further developments of this project (potentially, involving more direct interaction with live horses – rather than video data) were submitted to The University of Exeter's Research Ethics and Governance Office. This ethical review, occurred while the author was undertaking initial research, as described in this paper. Following discussion with ethics staff and a UK Home Office inspector - to consider any implications under The Animal (Scientific Procedures) Act 1986 (ASPA) – extending this research to work with live horses has been approved, without the requirement for a full committee application.

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